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Combining aesthetics and engineering specifications for fashion-driven product design: A case study on spectacle frames

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ABSTRACT

The successful combination of aesthetic and engineering specifications is a long-standing issue. The literature reports some examples where this problem was achieved developing tools to support the automatic generation of new product shapes, embedding and linking predefined rule-sets. Notwithstanding, these kinds of tools are effective if and only if the relations among these specifications are known. Other complementary strategies act upstream by building a common ground: they aid in the formalisation of these specifications, fostering the use of a shared language and the same level of detail. This paper lies in between the previous approaches since its purpose is the description of a strategy to formalise the relations among aesthetic and engineering specifications and whose validities are not affected by the product variability. Indeed, fashion-driven products are subject to continuous innovations and changes. Therefore the identification of these predefined rule-sets is challenging. In detail, the paper objective is to build a high-level and long-lasting formalisation of these relations, based on topological and functional rules. To demonstrate the effectiveness of this approach, we developed a case study in the eyewear industry. We started considering the spectacle-frame functionality and derived the high-level formulation linking aesthetic and engineering specifications. We used this formulation to generate an abstraction of the frame geometry, i.e., an *archetype*, to be used as a reference for the design of new collections. We implemented the *archetype* through a MATLAB script, and we translated it into a design tool, to wit an Excel spreadsheet. The validity of both the *archetype* and the tool has been tested, in collaboration with an eyewear manufacturer, designing and manufacturing two new models of frames.

1. Introduction

Nowadays spectacles are much more than devices for patients needing them for vision correction (e.g., corrective glasses) or protection (e.g., sunglasses): in years, fashion trends and the eyewear industry have transformed eyeglasses from being a medical device to a fashionable accessory. Indeed, nowadays it is not so uncommon to find people wearing spectacles without prescription lenses (e.g., see [1]).

This transformation has undoubtedly led to positive consequences for the acceptability of spectacles in the society, as also underlined in [2]. On the other hand, this strong focus on the aesthetic characteristics of the product is constantly pushing the limit in search of new style-lines through the generation of innovative shapes, and the introduction of new materials and surface textures. This innovation strategy, combined with the short (seasonal) time-to-market [3] as well as the hand-crafting essence which still characterises this industry (as an added value for the product), has made the work of engineers more challenging.

First, each spectacle — to be released as high-end wearable medical device — must fulfil a wide range of ISO standards (e.g., ISO 10685, ISO 8624, ISO 12870) and quality control requirements. The design process is thus characterised by a continuous search for the optimal shape, simultaneously fulfilling aesthetic, functional, and manufacturing requirements. However, if the fulfilment of the aesthetic demands represents a priority especially for certain collections, finding the optimum is not an easy task. It is emblematic, for example, that not all sunglasses of luxury

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collections can accommodate prescription lenses. Despite high-brand spectacles are usually characterised by a high level of design innovations, some models require lenses with base-curve radii or geometries, incompatible with non-neutral lenses due to thicknesses and shapes. The design process is thus characterised by many redesign and aesthetic approval cycles since there are no clear rules and indications which engineers can implement to correlate aesthetic-and-engineering specifications during the spectacle-frame design. This situation is even more stressed by a further element of complexity: the high variability of materials, colours, and shapes to be managed by the R&D departments in a short period, due to the seasonality of the market [4]. All these elements of variability are matched in almost unlimited combinations, to guarantee brand uniqueness.

To support the design of spectacle frames, in this paper we describe a strategy to conciliate aesthetics and engineering specifications. We considered fundamental to make explicit the hidden topological-and-functional rules that control the spectacle shape: the implementation of these rules should guarantee to the designers — on the one hand — the control over the product functionality and the manufacturing constraints, while — on the other — the possibility to freely modify this shape in order to fulfil the aesthetic requirements. These relations among the spectacle design parameters were used to extrapolate a universal representation — to wit a formalisation — of the frame geometry to be used as a reference whenever a new collection is designed. This reference frame, which we name *archetype*, can be used to master variability issues. Through this formalisation, we also aimed to generate new knowledge and to develop a dedicated tool to support the design of spectacle frames. We used the MATLAB® R2016a environment for a preliminary mathematical verification of the topological and functional relationships among spectacle components. Then, a Microsoft® Excel® 2016 spreadsheet was used to transform a simplified version of these relations into design rules, and to provide design inputs to the engineers. We performed a first geometrical validation of the *archetype* using the CAD system PTC Creo® 3.0. Finally, we validated the correctness of the topological rules as well as the effectiveness of the Excel® spreadsheet through a case study developed in collaboration with an eyewear manufacturer.

The contribution of the paper is thus twofold. First, from the application point of view, the proposed formalisation strategy represents a first attempt of this kind within the eyewear industry. The high product variability which characterises this industrial field — as a consequence of the continuous search for uniqueness and originality — makes this one a relevant research context for testing new effective strategies for conciliating aesthetic and engineering specifications. Indeed, considering how much aesthetics is playing a positive and relevant role in transforming the design of products, this conciliation is particularly crucial to change the social perception of those products used by people having impairments, as already done for spectacles (see [2]). Second, from the theoretical point of view, it demonstrates the effectiveness and the importance of combining aesthetics and engineering specifications, starting from the identification of the functional and topological rules. This kind of formalisation of the relations among product specifications transcends the product variability and — in a broader sense — also the specific field. Hence, although our formalisation strategy has been conceived for eyewear, it could be potentially implemented even for those products where fashion and aesthetics play a leading role in the design process.

The paper is structured as follow. In Section 2, we analyse the strategies already discussed in the literature to conciliate aesthetics and engineering requirements, and we also discuss the importance of looking for a reference model, when designing, acting as the link among different perspectives. Section 3 concerns the description of the research context, to better clarify the challenges that we had to address to support the design of spectacle frames. Section 4 is focused on the description of the formalisation strategy adopted to generate this reference model. In addition, in this section, we also describe how this model (i.e., the *archetype*) has been transformed into a design tool. In Section 5, we discuss how both the model and the design tool have been validated. Finally, conclusions are drawn in Section 6.

2. Background

The need of conciliating aesthetics and functionality when designing is something well-known both in the industry and in academia. Reaching such a holistic target is challenging due to, for example, the necessity to integrate all the different competencies and perspectives driving the development of the product (see [5]). In addition, design decisions should be taken not only considering the perspective of the end-user but also how much they will impact on the next phases of the development process, and on all the stakeholders involved (e.g., see [6]). Actually, interesting attempts have been already discussed in the literature. Some of them are discussed in this paper, clustered into two complementary groups.

On the one hand, several tools have been developed to guide product developers towards the automatic fulfilment of all the settled design specifications. Some of them are software tools conceived to suggest solutions or propose alternatives on the basis of predefined rules and constraints; others are conceived to stimulate the interaction and an active involvement of the various experts/stakeholders, facilitating the convergence towards a jointly approved solution. On the other hand, the effort has also been put on the importance of using a shared vocabulary and the same level of detail when describing these specifications. These approaches make easier the discussion about the relevance and the weight of the same specifications and the settled design targets.

Concerning the first group, for example, as underlined by [7], since separating form and function could lead to unexpected manufacturing issues, in their work the authors describe a computer-aided design tool which use rules (ergonomic, aesthetic, and manufacturing) to guide the generation of preliminary concepts of the new product. Being their generation "rules-driven", the settled requirements are automatically fulfilled. Another approach is discussed in [8], where an *archetype* is used as a starting point for generating new shapes through an evolution process conceived to take into account product requirements. In [9] the authors have embedded a model describing user's shape preference into a design optimisation algorithm. The intent is to provide a design tool able to suggest to the engineer the optimal shape which is the one satisfying both users' and engineering requirements. A different strategy to make easily converging the work of the stylist and the one of the engineer is described in [10]. In this work, the authors discuss a prototype of a desktop system able to automatically acquire in real-time the surface of the physical model elaborated by the stylist so as the engineer can immediately evaluate it and thus ask for changes when necessary.

Concerning the second group, as underlined, it is not only a matter of using the same terms but also the same level of detail when setting these specifications. Indeed, aesthetic requirements are usually expressed in qualitative terms. They are also difficult to catch since they depend on humans' needs and preferences. For this reason, several researchers are exploring strategies to help designers to translate these needs and preferences into quantitative indications. For example, in [11] a methodology based on the use of the Repertory Grid Technique is proposed to extrapolate and translate, into measurable requirements, the latent needs of